Chapter 5
Automation Considerations

5-1. Introduction

Automation of instrumentation can assist in the assessment of the safety of dams and levees. This is particularly true for monitoring that requires rapid and frequent data collection or for instruments that are inaccessible. In recent years, the technology of devices for measuring seepage, stresses, and movements in dams and levees has improved significantly with respect to accuracy, reliability, and economics. Although the initial installation of an automated data acquisition system (ADAS) may appear to be more expensive than traditional instrumentation systems, the overall long-term cost, in many cases, is now economically competitive. Automation should receive consideration for all systems that are to be installed during new dam construction, major rehabilitations, structural modifications, or any major effort that would support a major instrumentation system. Instrument upgrades and replacements could be justified on a case-by-case basis. The trends of decreasing manpower and resources that are allocated for dam safety efforts within the Corps of Engineers suggest that engineers consider the automation technology to accomplish the tasks required. The instrument automation concept generally includes an instrument or transducer that is linked to a datalogger or computer with communication capability that allows data retrieval locally or from a remote location. Figure 5-1 shows a general schematic of a typical ADAS. This chapter addresses areas that are characteristically unique for automation.

5-2. Applications

The monitoring of any project or feature can be automated depending on instrument type and feasibility. Automation is not limited to new installations related to new construction, research, or specific investigation. Existing systems can be retrofitted. However, it is not appropriate to automate in all cases. Sufficient engineering justification is necessary. The following situations are examples of justifiable applications for automating instrumentation.

a. Historical movement or pressure trends exceed the established thresholds, or trends are raising concerns that warrant frequent measurement.

b. Formal studies or investigations have identified specific or potential problem (stability, performance) areas warranting frequent measurement.

c. High hazard potential in the event of uncontrolled releases and timeliness of response to performance changes is critical to public safety. (Consequences of failure or partial failure)

d. Structural or foundation features are required to perform in a manner that was not anticipated in the original design.

e. Complexity of design and/or complexity of construction requires that design considerations be verified.

f. Abnormal extent or frequency of remedial measures has been or is required.

g. Instruments or systems have met their useful life, failed to perform satisfactorily, or have degraded with time and are required for performance assessment.

h. Timely response to unusual developments is adversely affected by remoteness of geographic location, inaccessibility, or lack of qualified onsite personnel.

i. Increased reliability and/or high frequency of monitoring is critical to the assessment of conditions.

5-3. Advantages and Limitations of Automation

The advantages and limitations of an automated system follow. The limitations can be minimized with appropriate attention to planning and use of the system.

a. Advantages.

- Increased accuracy-reduced human error.
- Increased frequency-more data, less system error.
- Increased data reliability and consistency.
- Replaces lost manpower.
- Timeliness of information-obtain data whenever needed.
- Data and system validity checks enhance data quality.
- Alarms for exceeding data thresholds and system health.
- Remote diagnostics, calibrations, and programming.

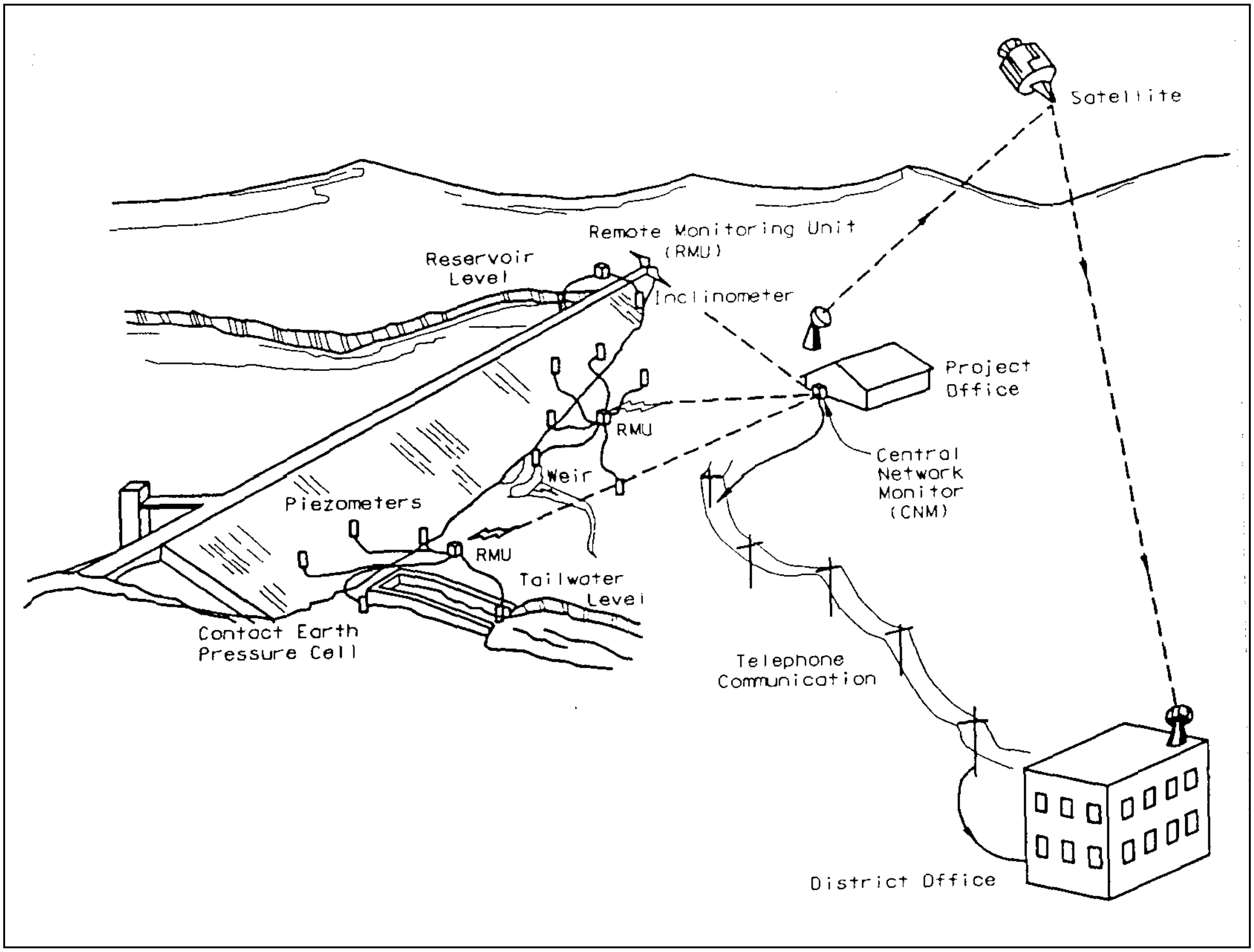

Figure 5-1. Automatic data acquisition system geotechnical instrumentation

b. Limitations.

- Produces large volumes of data; overtaxes storage medium.
- Installation could be expensive.
- Removes personal attention from the field.
- Lightning; variable voltage potential is destructive.
- Excessive downtime with overly complex integrations.
- Sufficient computer and electronics expertise not available.
- Potentially higher maintenance costs.
- Requires a constant electrical power source.
- Requires use of electronic transducers which have least long-term reliability of any type used.

5-4. Description of Automated Systems

Automation is the integration of the electronics, computer, and communications technologies that is applied to geo-technical and structural engineering concerns of water resources projects. It performs a variety of tasks that contribute to efficient and effective performance analyses. EM 1110-2-2300, Appendix D, very generally describes the features and capabilities of an automated system. The appendix contains examples of networks and communications alternatives. It also recommends an approach to choosing the features of a structure to be monitored and selecting the sensors that are appropriate to automate.

a. Configurations. Configurations of automated systems can be categorized as one of three basic types as follows:

(1) Datalogger. An electronic component collects data from attached instruments upon command from a personal operator. The system can include modems for remote communication, but generally requires that the intelligence and operation be external to the system. Figure 5-2 shows a stand-alone datalogger configuration.

(2) Scada. Scada (supervisory control and data acquisition) is a host computer that controls remote monitoring units (RMUs) which are intelligent dataloggers. RMUs acquire data and report those data upon command from the host computer. The remote unit can carry out the acquisition of data and store the information until communication with the host computer is established. The host computer is the system intelligence. It is programmed for frequency and scheduling of data acquisition. Personal intervention is not required for this system to operate. Figure 5-3 shows a Scada configuration.

(3) Distributed intelligence. Computers are located at each remote monitoring unit in the network. All are linked to a central computer; central network monitor (CNM) and communications can be established with the central computer as well as with each other. The remote units are fully responsible for the frequency and scheduling of data acquisition as well as initiating communications. Raw data can be reduced and certain other decisions can be made at these remote points without personal or central computer intervention. Figure 5-4 shows a distributed intelligence configuration.

b. Communications. Communication of information occurs at three different locations: sensor to datalogger, remote dataloggers to central computer, and central computer to remote office. The most common modes of communicating from the sensor to the datalogger are electrical transmission through cables and sound transmission (acoustics) through the air. The most common local communication, linking the remote units to the host or central computer, is electrical cabling or radio transmissions. Remote communication from the project site to the district office is commonly by telephone, microwave, radio, or satellite. All modes of communication are not appropriate for any one application. Consideration must be given to lightning, presence of water, and other conditions which would affect the selection of a mode of communication. Design criteria will assist in making that determination.

c. Power supply. Automated systems can be energized by alternating current, battery, or solar panels and are normally supplemented by uninterruptible power supplies or emergency generators. Each of these alternatives have positive and negative characteristics for various applications. The sizing and maintenance of the primary supplies and backups should be addressed early in the planning process.

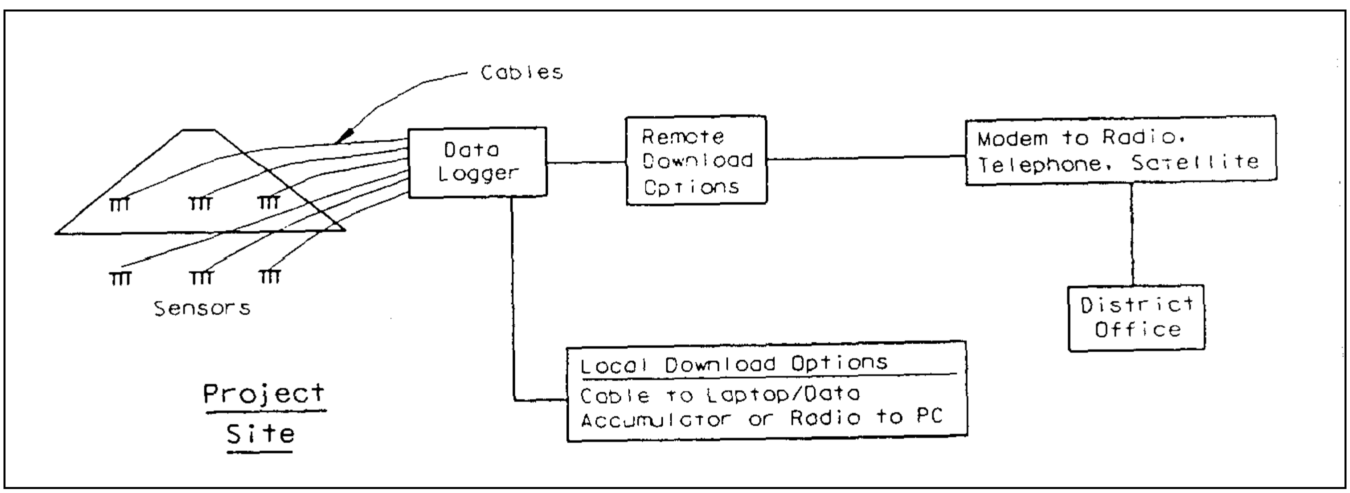

Figure 5-2. Stand-alone datalogger configuration

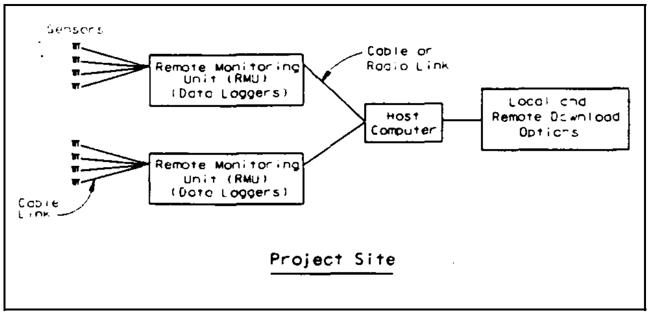

Figure 5-3. Scada configuration

5-5. Planning a System

All of the Corps of Engineers guidance and documentation that have been published emphasize that the proper approach to planning a system that is reliable and cost-effective include: obtaining the appropriate information, applying good engineering judgment, using Corps expertise when available, and learning from the experience that has been gained by others. The specific guidance is described below:

a. Detailed planning. Experience has shown that dam safety engineers must have some knowledge of project management and procurement issues to be successful with their automation endeavors. Experience has also shown that there are certain characteristics inherent in automation that must be understood to enhance the success of the project. This planning tool addresses the following major issues: assessing in-house resources, determining contracting mechanism, preparing Commerce Business Daily announcements and bid documents, technical design considerations, estimating, and others. Refer to USCOLD 1993 for more detail in each of these areas. It is important that the planner follow the suggested order of the tasks in the procedure to avoid complications at later stages of the planning process.

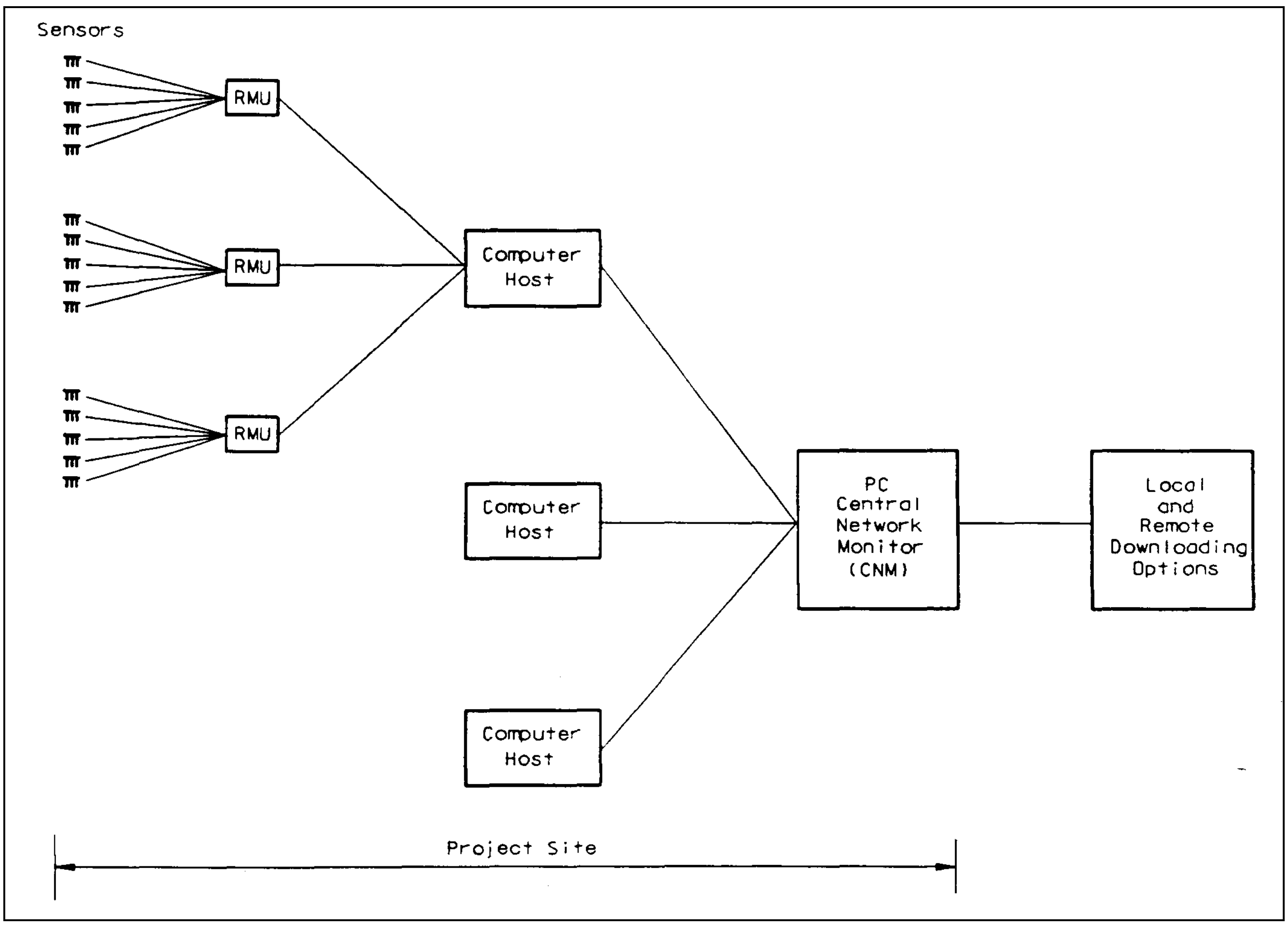

Figure 5-4. Distributed intelligence configuration

b. Automation experience. USCOLD 1993, Appendix D, is a summary of automation experience in Federal and private sectors. It lists dam projects and various features of dams that have been automated, the equipment used, the sensors installed, and persons that can be contacted for each of the projects listed. This document is valuable to designers that are interested in learning about the performance of systems that they are considering. Contacts with those persons listed should be an early step in the planning process to identify the feasibility of proceeding with the project and the appropriate direction.

c. Technical expertise. The majority of automation design, operation, and routine maintenance can be accomplished by conscientious geotechnical engineers, and moderate levels of computer and electronic expertise, most of which is available within the Corps installation. New automation developments and complex applications will often require a higher level of expertise which may only be available through contractor support. Lack of in-house computer and electronic expertise may also require a dependency on consultants and manufacturers to design, install, troubleshoot malfunctions, and implement corrections. Because of this contractor dependency it is highly desirable to specify a number of performance tests of all features of the system. Simultaneous manual and electronic data acquisition should also be accomplished during system performance testing. An increased level of cost will be proportional to the degree of dependency on outside expertise. This should be considered when planning and designing automated systems. Several Corps of Engineers Districts as well as WES have a significant amount of expertise in planning, design, and system operation and maintenance. Emphasis is placed on the use of in-house expertise as a priority with outside assistance (consultants, manufacturers, etc.) used as necessary.

d. Selection of instruments. If there is sufficient justification for automation (see paragraph 5-2), and preliminary assessments indicate that automation is feasible, judgment must be applied to the selection of instruments to be automated. Table 5-1 lists the methods and relative ease of automating various dam safety instruments. The following criteria should be considered when choosing instruments to be automated:

(1) Performance. Instrument performance is acceptable. Data are consistent and meaningful. Maintenance/calibration has not been excessive or ineffective.

(2) Longevity. The instrument is expected to continue to function for at least 5 years.

(3) Location. The physical location of the sensor (including the tip elevation and material type) is appropriate to monitor the feature/condition of interest.

(4) Ability to be automated. The instrument is able to be automated. Sensors are available and compatible with the current installation such that manual reading capability can be retained as backup. The new sensor will satisfactorily perform in an automated environment (response frequency, electronic conversions, communications media, etc.).

5-6. Designing an Automation System

CWGS 16740 is technical guidance for the instrument system designer. It addresses important issues that are characteristic of automated systems that demand attention, i.e., grounding techniques for lightning protection, the use of shielded cable, proper power supplies, etc. The guide specification is not a specific recipe but design and installation considerations for engineering judgment.

5-7. Implementation

Obtaining funding support for automation is often a concern. The best opportunities for implementing automation is for projects that are under construction (new projects, dam safety remedial efforts) and approved structural modifications, investigations, and research. Smaller projects may be accomplished with routine allocations of operations and maintenance (O&M) funds which are normally limited.

5-8. Data Acquisition, Management, Analysis, and Reporting

These issues are discussed in Chapter 7. That information is applicable to automated systems. In addition to that discussed, automated systems can provide large quantities of data at no additional cost. Discrete management of this volume of information is necessary to keep it from exceeding storage, to reduce time involved with communications, and to prevent it from becoming cumbersome when processing, analyzing, and reporting.

5-9. Maintenance

Utilizing data to determine the need for maintenance is discussed in Chapter 7. That approach is also applicable to automated systems. Automated systems can produce a large volume of data that are accessible on a very frequent basis. This provides greater opportunity to assess

Table 5-1
Methods and Ease of Automating Various Instruments (Adapted from USCOLD 1993) (Continued)

	Category					
Instrument[1]	1	2	3	4	Automation Method	Manual Backup
Piezometers						
Open standpipe		•			Pressure transducer down standpipe	Usually straightforward by measuring to water surface
Twin-tube hydraulic		•			Pressure transducers connected to lines	Straightforward, by existing pressure gages
Pneumatic			•		Pressure actuating and meas. system	Straightforward, with manually operated readout
Vibrating wire		•			Frequency counter	Ditto
Electrical res. strain gage		•			Strain gage, completion circuitry	Ditto
4-20 mA pressure transducer	•	•			Current readout	Ditto
Sonic		•			Time readout	Ditto
Deformation Gages						
Tiltmeter[2]	•	•			See footnote 2	Ditto
Probe extensometer				•	N/A	N/A
Embankment and borehole extensometer[2]	•	•			See footnote 2	Straightforward, with manually operated readout
Inclinometer, probe type				•	N/A	N/A
Inclinometer, in-place type[2]		•			See footnote 2	Straightforward, with manually operated readout
Plumb line and inverted pendulum[2]			•	•	Infrared or light sensor line position transducers	Ditto
Liquid level gage[2]	•	•			Pressure transducer	Ditto
Earth Pressure Cells						
Pneumatic			•		Pressure actuating and meas. system	Ditto
Electrical res. strain gage		•			Strain gage completion circuitry	Ditto
Load Cells and Strain Gages						
Electrical res. strain gage		•			Strain gage completion circuitry	Ditto
Vibrating wire		•			Frequency counter	Ditto
Hydraulic load cell		•			Pressure transducer	Ditto
Temperature						
Thermistor	•	•			Resistance readout	Ditto
Thermocouple		•			Low level voltage readout	Ditto
Resistance temperature device	•	•			Resistance readout	Ditto

There are four categories in order of increasing difficulty, specialization, and cost of automation:

CATEGORY 1: Straightforward. Category 1 can be done by numerous manufacturers of laboratory and industrial ADAS.

CATEGORY 2: More Specialized Requirements. Thermally unconditioned environments, inaccessible power, nonstandard signal conditioning, low level voltage measurement, wide common mode voltage range.

CATEGORY 3: Most Specialized Requirements. Hostile outdoor environment, hard-wire communication unavailable - radio network required, difficult sensors to automate like plumb lines and pneumatic piezometers, sensors which communicate via serial or parallel interface.

CATEGORY 4: Usually Not Practicable to Automate. Technical complexity or cost outweighs benefits, significant reliability problems in hostile environment, customized automation hardware required, impracticable to automate.

[1] For a definition of instrument terms, see this manual and Dunnicliff (1988).
[2] Depends on type of transducer.

Table 5-1 (Concluded)

	Category					
Instrument	1	2	3	4	Automation Method	Manual Backup
Miscellaneous						
Reservoir and tailwater elevation, rainfall gage[2]	•	•			See footnote 2	Ditto
Weir for measuring water flow[2]	•	•			See footnote 2	Ditto
Seismograph analog				•	N/A	Seismographic chart record
Seismograph digital		•			N/A	Seismographic chart record

instrument performance easily and often. Additional discussion regarding calibration is in Chapter 8 and it is also applicable to automated systems. Some components can be calibrated with expertise already existing at many Corps installations; other calibrations can be accomplished with minimal training and additional equipment. Calibration of custom-developed components could require the attention of outside expertise.

a. Planning. Automation experience has indicated that maintenance can be minimized with proper planning and forethought. The following is suggested:

(1) Determine the person(s) responsible and the means of accomplishing the maintenance as early as the planning and design phases of the project.

(2) Obtain clear, simple documentation, O&M manuals, as-installed drawings, and electronic schematics from the contractor and/or manufacturer.

(3) Involve the operation and maintenance personnel in the planning and design phases as well as during the installation and acceptance phases.

(4) Use the component concept to facilitate changing malfunctioning devices with spares and/or replacement parts as necessary. Use equipment that has standard connectors, parts, and operating procedures to assure compatibility with a variety of manufacturers of similar components.

(5) Obtain manufacturer-recommended spare parts with the initial system. Revise the inventory as consumption rate is learned.

(6) Train the maintenance staff and system operators. Retrain them as personnel turnover and/or system changes necessitate.

(7) Learn the performance characteristics that are unique to the system and utilize the remote diagnostics.

(8) Use project blanket purchase agreements (bpa's) or other existing mechanism for components already being maintained on site (radios, personal computers, telephones, etc.)

(9) Take advantage of warranties. Check the performance of all features of the system before the warranty period expires. Remote calibration, diagnostics, reprogramming, and troubleshooting are examples of system features that may be rarely or infrequently used. Unsatisfactory performance of such features may escape warranty attention if not checked.

b. Implementation. Indefinite delivery contracts and maintenance agreements with manufacturers are the most expensive means of maintaining systems and they tend to remove the system users from thoroughly understanding the system.